SD 0725

Anytime Coach

Your Ultimate MP3 Jukebox

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Glossary

From here in the following terms mean as explained

Device – Device means ‘Anytime Coach’

Voice Lesson – An MP3 audio stream that would be recorded voice instead of a song. This voice lesson could be recorded for teaching or directing the user to do a specific task while exercising, while use at a gymnasium. Alternatively, it could also contain a description of any artifact when in use at a museum. It can be anything as desired by user.

CD Quality – The CD quality is a standard established as 128 Kbps at 44,100 KHz.

Training Mode – Voice-over mode of the device where it plays two track simultaneously.

1 Overview

Our goal was to develop a portable multiple source MP3 player that is capable of automatically and smoothly superimposing one audio source over another. The music volume is temporarily lowered (but still audible) and returns to normal volume whenever the voice-over is done. Second-source voice-over audio can be automatically triggered by RFID or selected at will of the user.

One implementation of this could be for use as a "virtual personal trainer": during your workout you will be able to listen to the music of your choice and at selected intervals (depending on the equipment you're using at the moment) a pre-recorded (yet customized) personal trainer voice-over will direct your reps and provide motivation. Another implementation of this technology could be as a “virtual tour guide” in the nature of a tour, in which you can randomly move about to selected sites and receive information about it upon arrival through your player.

2 Requirements

The project incorporates four independent requirements and the integration of the following technologies to achieve desired functionality.

i. MP3 Player
ii. Voice – Over Technology
iii. Connectivity to an access point
iv. Device identification

2.1 MP3 Player

The requirement is of a standard MP3 player capable of playing MPEG – I, II audio streams. An LCD display and push-button support for the user interaction and device operation. A jog dial could be a future possibility. Memory support up to 2 GB but at least 512 MB is desirable.

2.2 Voice – Over Technology

The voice over technique implies the ability to play two tracks simultaneously. The player will play a song at random with a specified / pre-determined (selectable) voice lesson[1] at CD quality[2]. This feature would enable the use of a device as described in section 1. Also when the device functions in this mode it should lower the volume of the song as if it is playing in background. The strength of the voice lesson shall be more pronounced.

2.3 Connectivity to Access Point

The device needs to have a capability to communicate with another device possibly a local computer using a standard communication protocol as Bluetooth, or Wireless. This would be used to download the voice lessons.

2.4 Device Identification

This would be used to determine the voice lesson, discussed in section 2.3, to be downloaded and played. The device, for which lesson needs to downloaded would be identified using RFID technology with a range of less than 1 ft.

3 Design

3.1 Product Model

The player has broadly two domains of operation. One is to play song as a standard MP3 player would do. The second is to play another set of MP3 tracks downloaded and temporarily saved to the mass storage media (SD Card). A top-level design describing the main functions of the device is shown below.

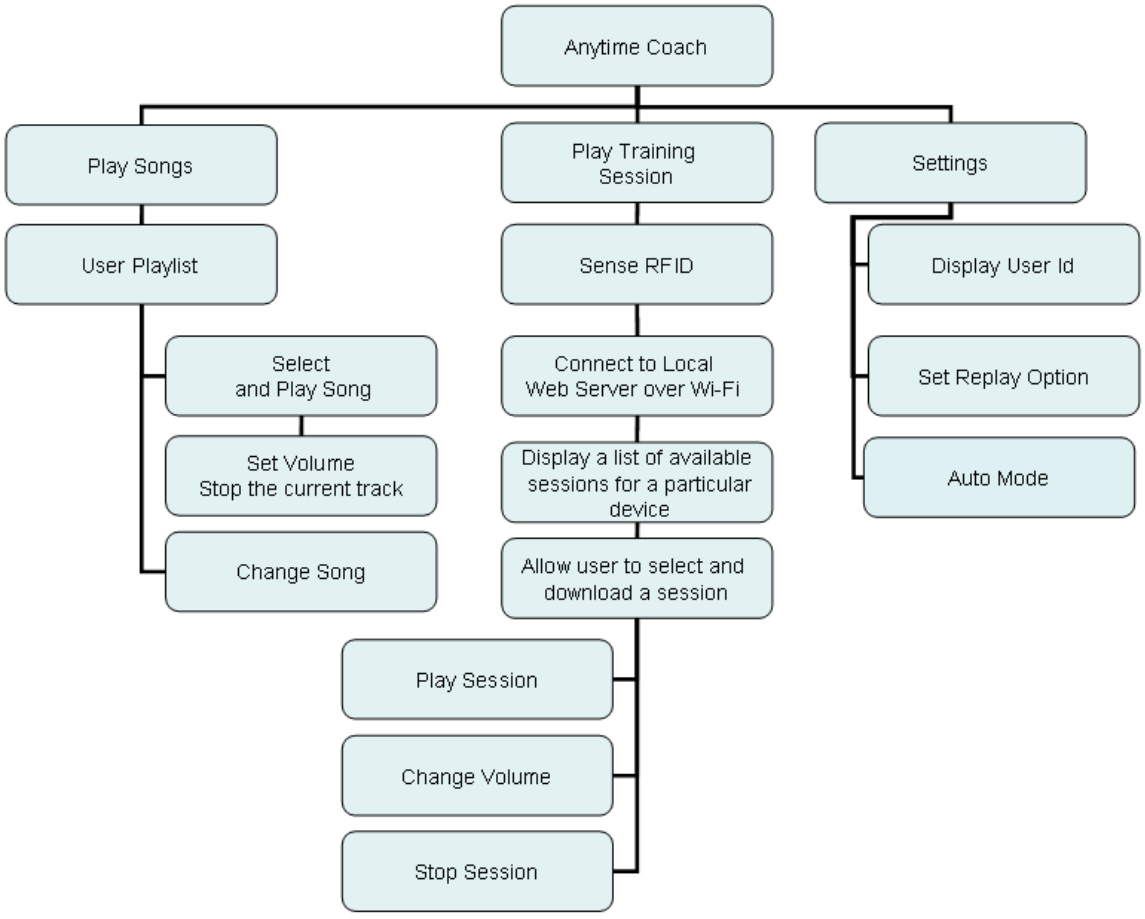


Figure 1: Conceptual Model

The Play Song section provides user with following capabilities

1. Playing his MP3 tracks all in a folder named MUSIC on the SD Card. Currently, user is not allowed to have multiple folders/sub-folders or tracks in a folder other than the MUSIC folder.
2. Changing/stopping the current music tracks on the fly and adjust volume.

The Training section allows user to

1. Sense a near by RFID tag
2. Download a list of available sessions for training though Wi-Fi.

For this the user has to enter the Training Mode and If no RFID device is detected the system returns to the previous menu. If a device is detected the system automatically tries to connect to the local server and get information for the sessions available to him for training. If no sessions are available then a short message is displayed and the system then returns to the previous menu. If there are sessions available then system waits for user to select a session. Upon selection the system downloads files for that session and then automatically starts playing the first track for the training session. After playing the first track of the session the user may have to press a key for playing the next session depending upon the settings.

The Settings section allows user to select a replay mode for the music tracks. The auto mode allows user to automatically change session tracks. Additionally, it also displays the user-id of the player which is required for using the training mode of the device.

3.2 Hardware Design Model

The system uses a Rabbit RCM3010 core module with Rabbit R3000 processor. It has 128 KB of RAM and 256 KB Flash memory. It interfaces and controls all the other components and sub-systems i.e.

1. 20 x 4 LCD display
2. 4 button switch panel for user input
3. RFID tag reader
4. Wi-Fi module
5. SD Card reader module
6. MP3 Decoders

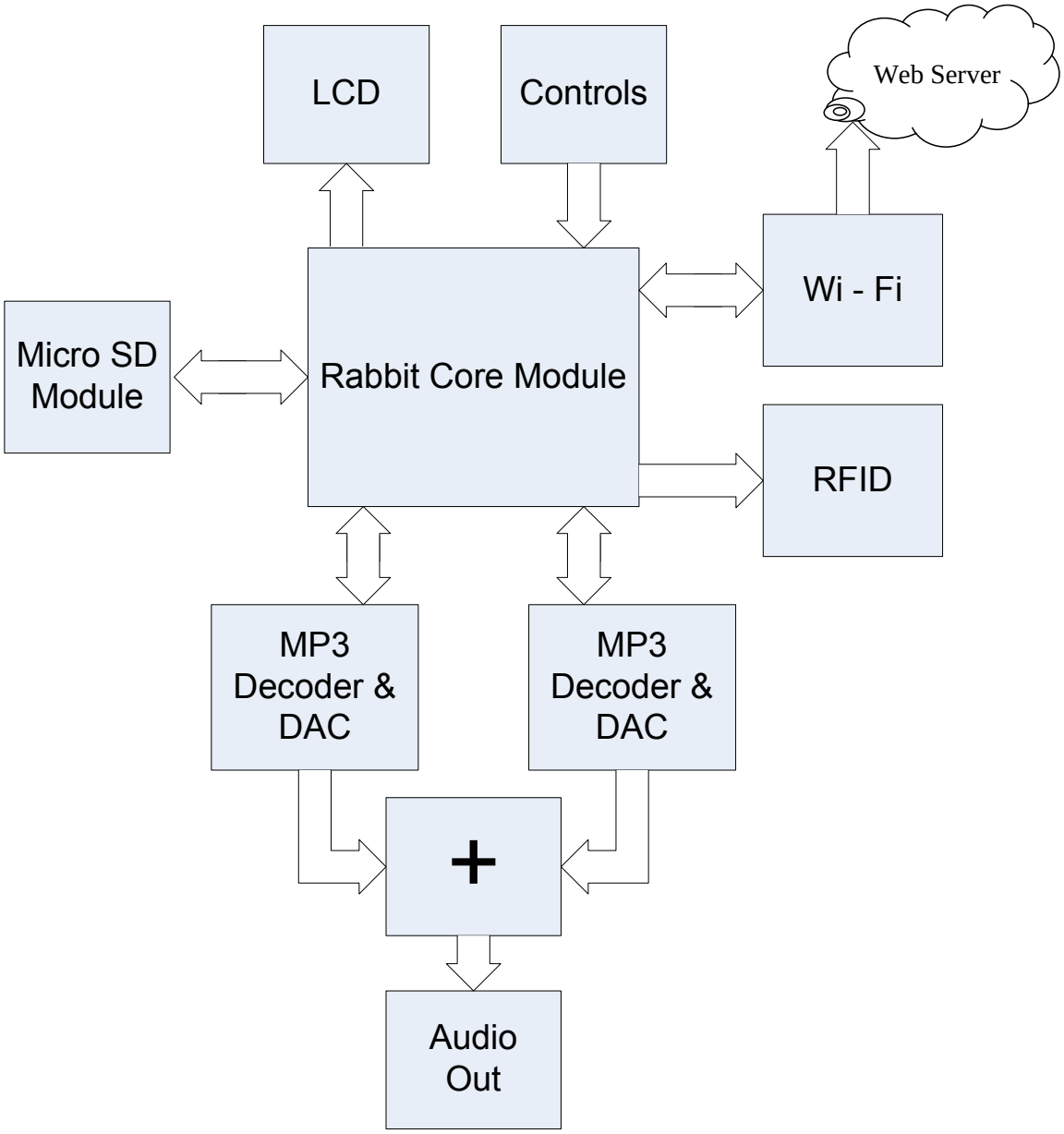


Figure 2: Hardware Design Model

3.2.1. LCD Display

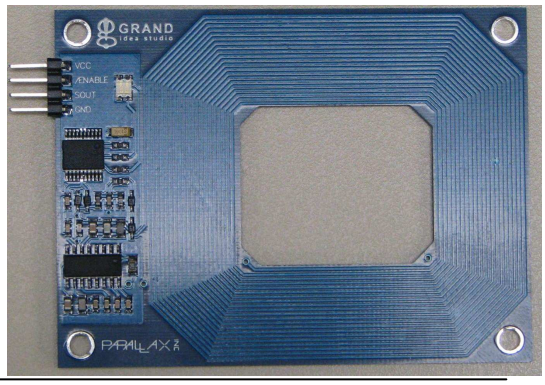
The device uses a 20 x 4 monochromatic backlit LCD display from Parallax Inc. (Part No: 27979). It works on a 5V supply and has a UART interface. The UART interface has only one line, Tx. Data is sent over this line at 2,400 Baud in ASCII format. It supports baud rates of 9,600 and 19,200 but we use 2400 Baud only because this saves a Serial Port whose Receive line is multiplexed with the RFID Reader module. Although, it is possible to get the LCD work at higher baud rates but it will require some additional hardware and software changes.

Figure 3: LCD

3.2.2. Switch Panel

The switch panel consists of four momentary push button switches (Part No: EG-1301). They are used for user input. All the switches are used for navigating* through the menu. Two are used for 'Select' and 'Back', while other two are used to move 'Up' and 'Down'.

3.2.3. RFID Reader

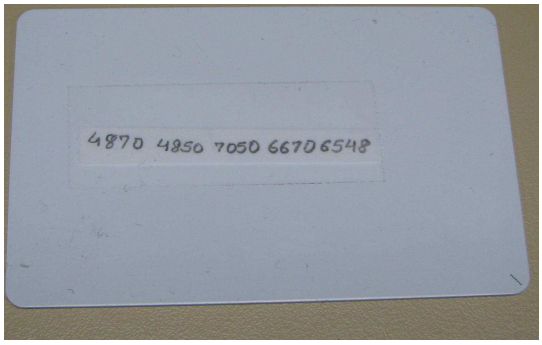


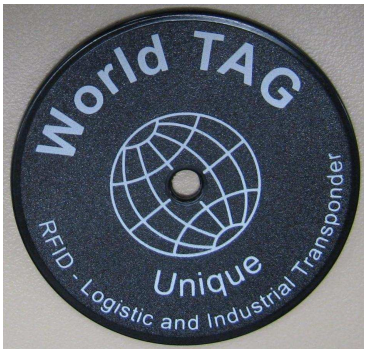
RFID stands for Radio Frequency Identification Devices. The RFID reader is also from Parallax Inc. (Part No 28140). It works at Freq and uses access control type tags. The Reader has a planar antenna on both the sides and is capable of reading RFID

tags from a close distance of 4-6 inches. This distance is ideal from the point of view of application because it will prevent interference amongst tags placed in close proximity to each other, which is likely as the device is meant for indoor use.

The RFID tags (Part No: 28141-2) used are also from the same vendor. These are passive tags and therefore have a fairly limited range as described above. Also, these tags are nominally priced and can be replaced without any issue. However, the newly replaced tags have to be registered into the database before they can be used. Each tag has a unique 20-digit ID which provides the option of using 10^{20} unique devices.

The RFID reader draws power heavily when in active mode as opposed to inactive mode when it demands virtually no power. Therefore, it has been programmed to be activated temporarily only for a short duration upon user request, to maximize the battery life.



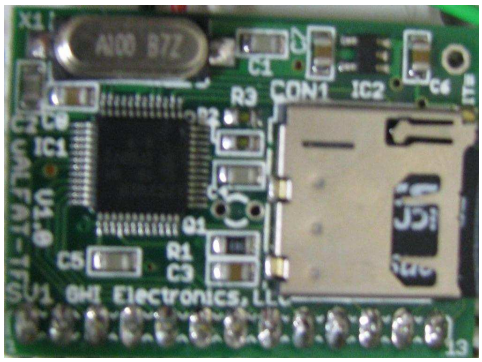


3.2.4. Wireless Module

The system uses a standard compact flash Wi-Fi card that is interfaced with the micro-controller using through a Wi-Fi add-on kit from Rabbit (Rabbit 3000 Footprint Wifi Add On Kit). It operates in 2.4 GHz range ISM band, and is compatible with networks supporting IEEE 802.11b standard.

3.2.5. SD Card Module

The memory module consists of a micro-SD Card. The file system is FAT 32, which has been implemented using a µALFAT module for GHI electronics. The module takes care of the files system which is transparent to us. It has its own command set for communication. It support



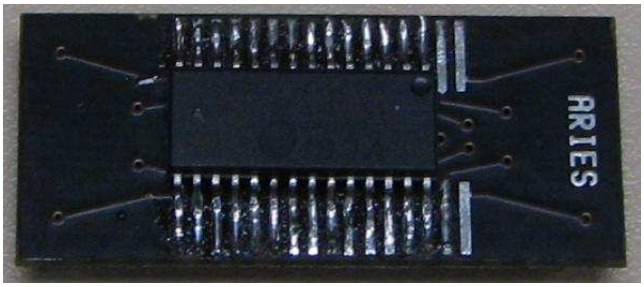
UART, I2C and SPI interfaces. However, UART was found to be unreliable as it was missing bytes in between. As a result this could not be used because it would cause corruption of data and/or poor sound quality because MP3 is an encoded format and missing bytes results in entire frame being dropped.

We have incorporated SPI mode for our device which however is slightly different in its implementation. The SPI bus doesn't send in two special characters, 0xFE and 0xFF. The SPI bus protocol uses these two bytes as control characters and for receiving and transmitting these characters a format is followed. The datasheet for the module refers to 0xFE as Half Data Token (HDT) and 0xFF as No Data Token (NDT). To communicate 0xFF we send/receive a HDT and any other character from 0x00-0xFD and two HDT(s) for 0xFE. So, this adds up to additional processing over head.

3.2.6. MP3 Decoders

The MP3 decoder(s) in use are from VLSI Solutions, (Part No: VS1011e). It is capable of decoding MP3, WMA and WAV files. We communicate with it over the SPI bus. The decoder requires binary MP3 data to input into it. It itself extracts all the information for sample rate, bit-rate, channel, etc. from the MP3 header. Additionally, it automatically ignores any corrupt data.

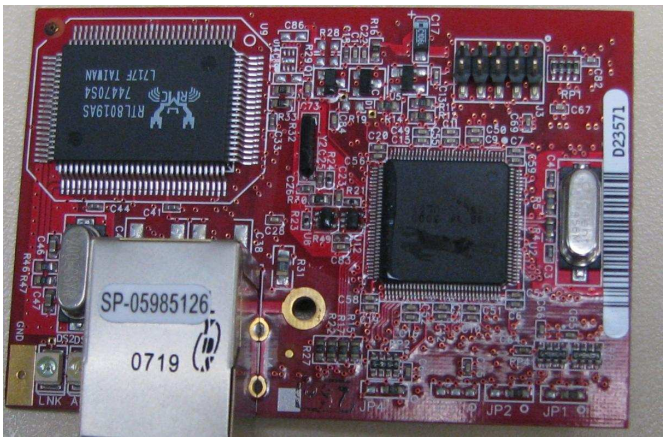
The decoder also has an in-built DAC (Digital-to-Analog converter) and the basic circuitry required to drive 30Ω load.



3.2.7. Rabbit Core

The Rabbit core module uses a Rabbit 3000 processor. Capable of performing at 29 MHz, it has an onboard Flash memory of 256K and base RAM of 64K and extended RAM of 64K. Additionally, it has an onboard Ethernet port and is capable of support a Wi-Fi module using an add-on kit.

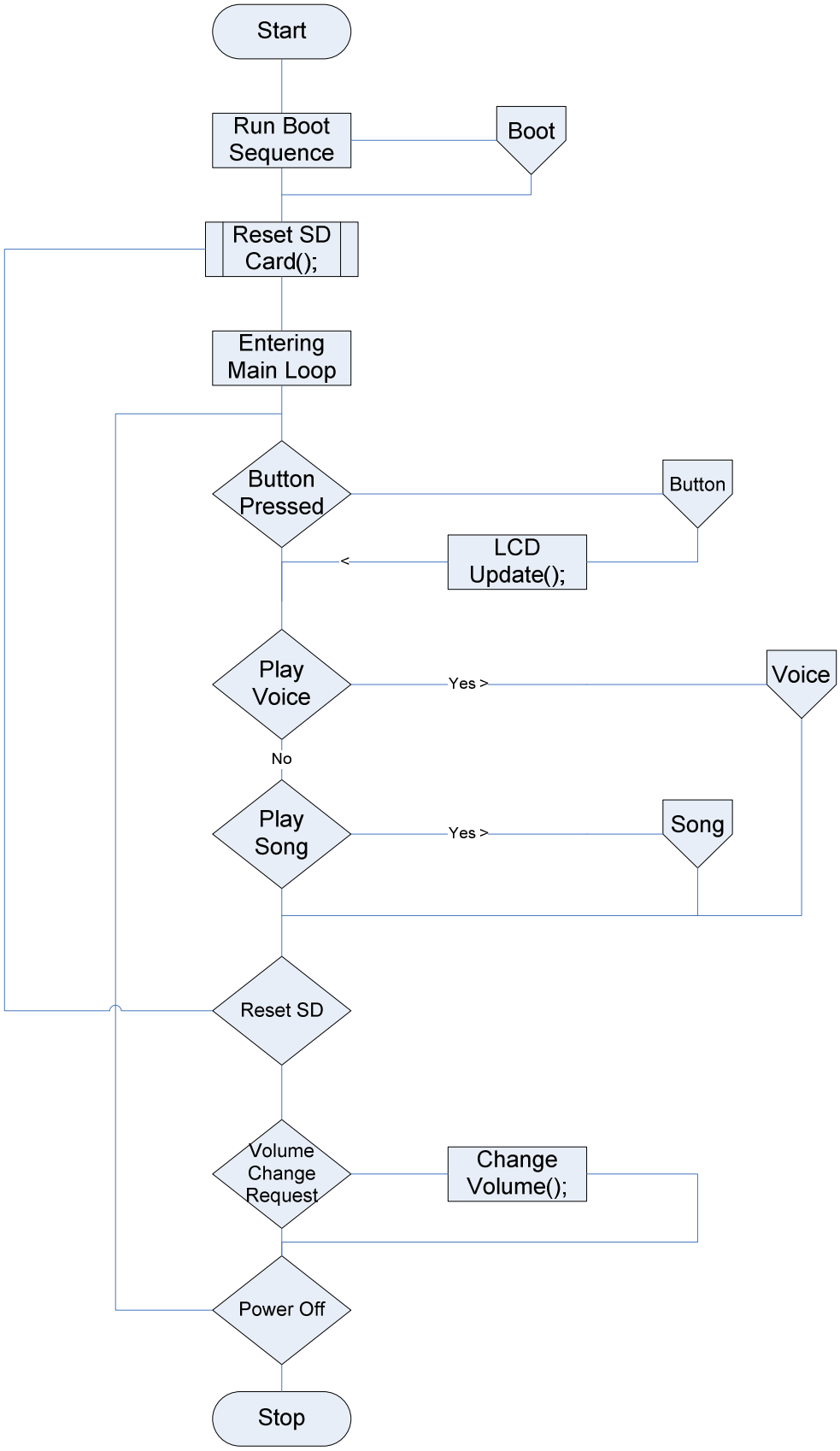
This comes with a rich library of functions and basic routines for implementation of TCP/IP stack. It also has 6 Serial ports and 7 parallel ports that provides us with a huge range of possibilities to use all the various devices and subsystems.

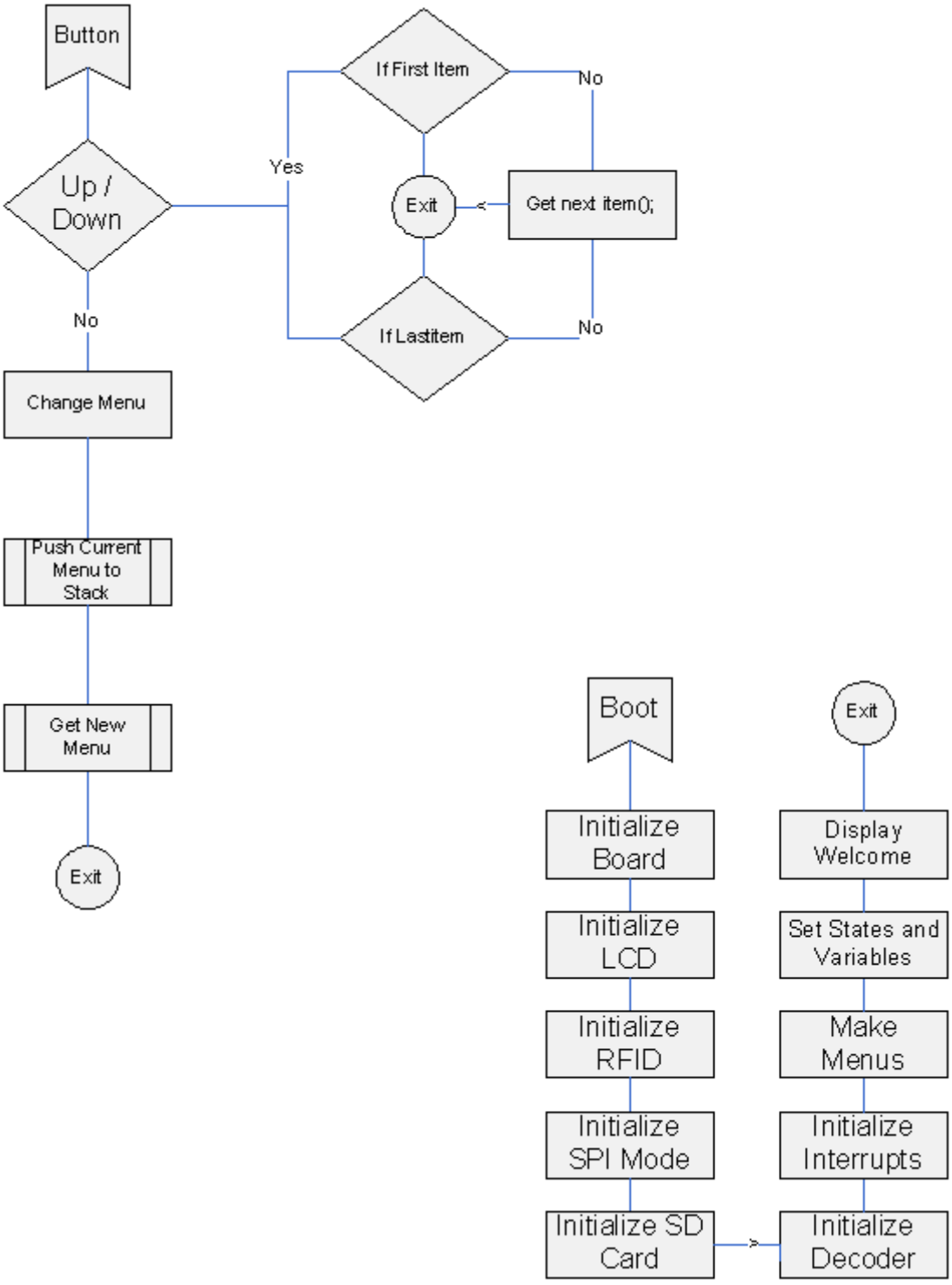


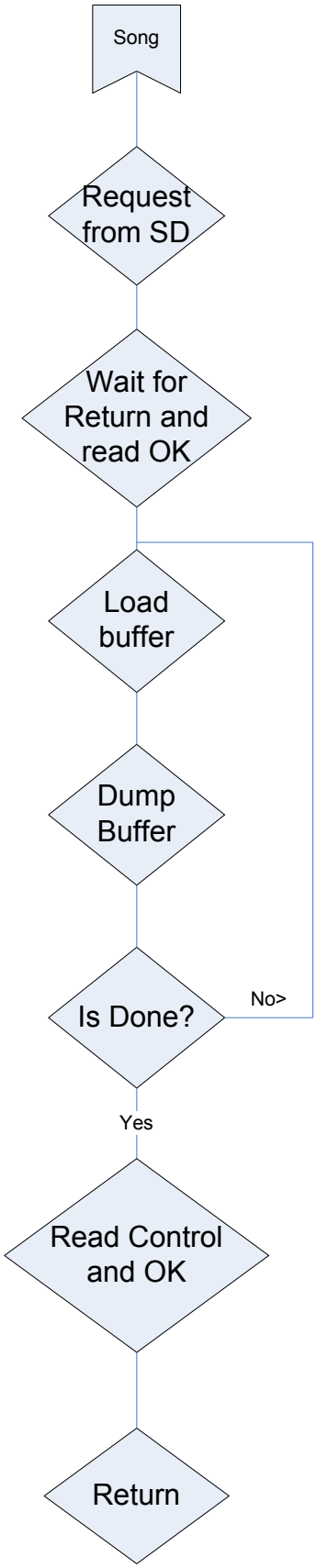
3.3 Software Design Model

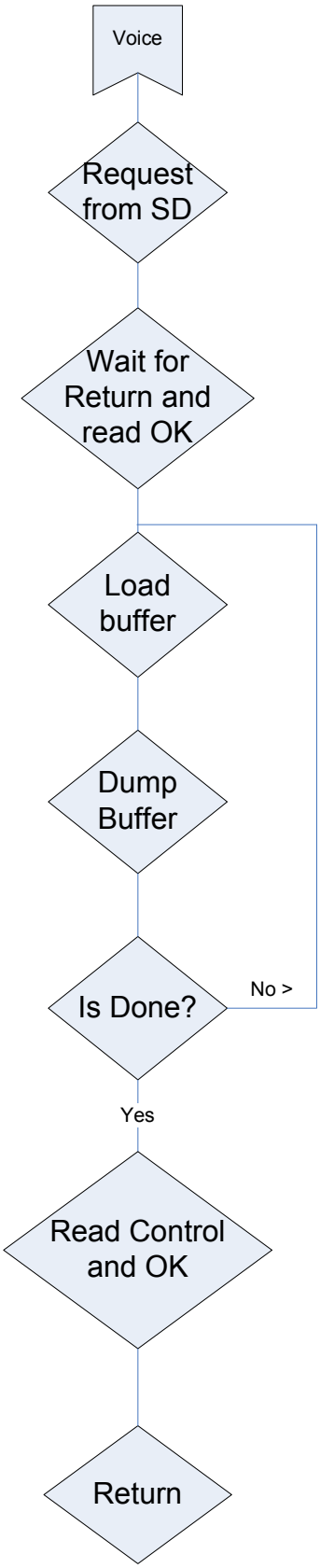
The software for the device has been written in C using DynamicC, which is also a proprietary tool that comes with the core module. Below is the main program that controls everything. We begin with set the port setting and then reset all components and then put them into ready state.

After running the boot sequence we enter our main and check for various system states and have them executed upon required value. All the other routines are executed from the main on the basis of flags or system states. The following flowcharts the software design been followed.


Start
Run Boot Sequence
Boot
Reset SD Card();
Entering Main Loop
Button Pressed
Button
LCD Update();
Play Voice
Yes >
Voice
No
Play Song
Yes >
Song
Reset SD
Volume Change Request
Change Volume();
Power Off
Stop

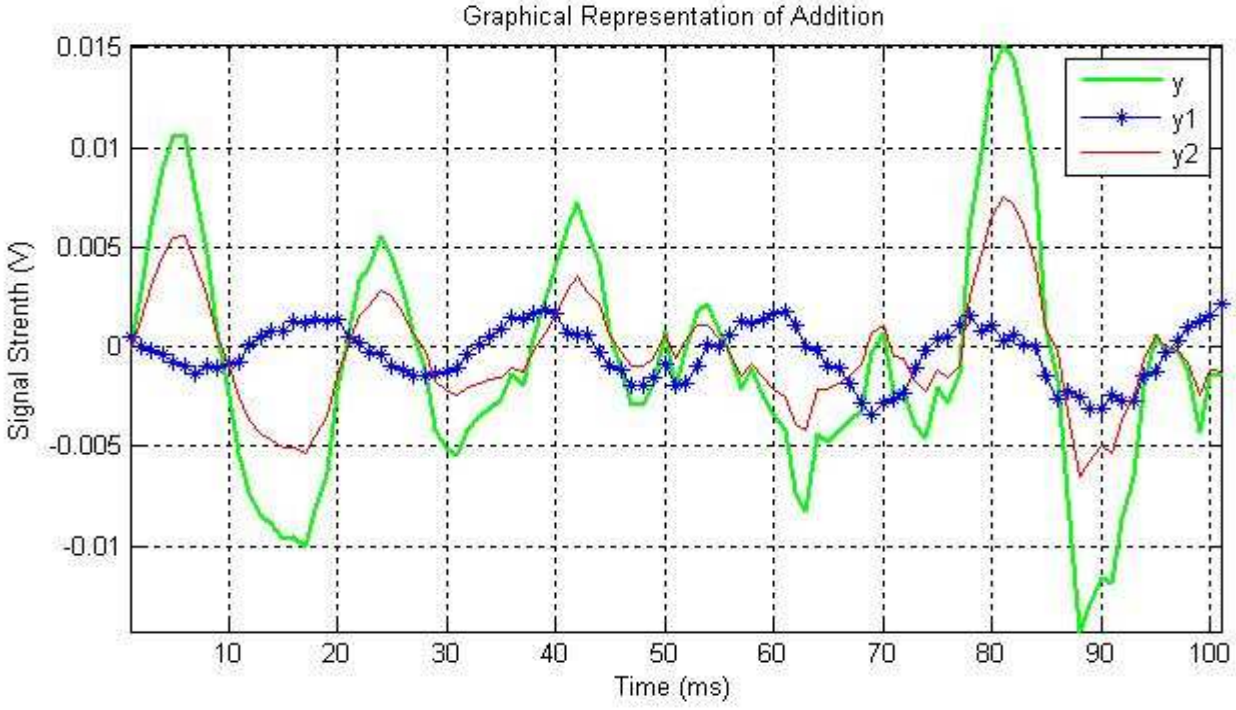

Button
Up / Down
No
Change Menu
Push Current Menu to Stack
Get New Menu
Exit
Yes
If First Item
No
Exit
Get next item();
If Lastitem
No
Boot
Initialize Board
Initialize LCD
Initialize RFID
Initialize SPI Mode
Initialize SD Card
Exit
Display Welcome
Set States and Variables
Make Menus
Initialize Interrupts
Initialize Decoder


Song
Request from SD
Wait for Return and read OK
Load buffer
Dump Buffer
Is Done?
No>
Yes
Read Control and OK
Return

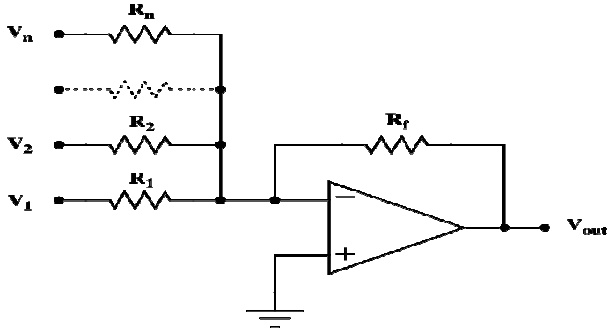

Voice
Request from SD
Wait for Return and read OK
Load buffer
Dump Buffer
Is Done?
No >
Yes
Read Control and OK
Return

3.4 Voice over theory

For the voice over part we need to add the streams in a synchronous manner. The voice over algorithm was difficult to guess initially but the principle is simple and most of us know that. It works on principal of superposition. The addition has been tested at in software using MATLAB by giving double weighting to the signal Y. The other signal in the picture is Y_2. $Y_1 = Y_2 + Y$.



In hardware it has been implemented using a summing amplifier. The two outputs from the MP3 decoders were fed into a summing amplifier and the output was connected to the audio jack. This is done separately for each channel.



3.5 User Interface

The user interface consists of an LCD display and 4-Momentary push buttons. For more details refer to Users Manual and section 3.2.1 and 3.2.2

3.6 Web Interface

The web interface consists of a web-server that needs to be running at a local location. It consist of

1. HTTP Server
2. PHP Server
3. Database manager

At present we are running an Apache 2.0 HTTP web-server that provides us the front-end connectivity, including the HTML pages that allow application control. For database we are using a MySQL server which is provided back-end connectivity through a PHP server.

4 Troubleshooting

4.1 User Device

At startup when you see the main menu being displayed the following pin states should be tested against the following. The following pin tests can be done to check which device is faulty

Sub-system	Pins	State
Rabbit	PC3-0	High
	PD4-3	High
	All pins on port F	High
	PG1-0	High
	PG3	High
	PE0	Low
	PG7-4	Low
MP3 Decoder	RCap[#]	1.3 V
SD Card Module	VBat[#]	3.3 V

[#]Refer to datasheet for pin reference.

Also check whether the oscillators are working or not.

4.2 Server Interface

Check whether the server is running or not and whether you can access the system control page from another PC or not. If that is the case you need to restart the server or otherwise the device will fail to connect.

Also make sure that the network you are on is a compliant network. See appendix for details.

If you are sure that the network and the server are running then you should test whether the LED on the CF Wi-Fi card is glowing. If not then test whether the board has power or else check that the card works when plugged into a CF port on a PC. If not, you might be required to replace the Wi-Fi card.

5 Appendix

A) Device Specifications

Specification	Value	Unit
Voltage Supply (4 AA Batteries)	6.0	V
Max Current Rating	200	mA
Max Output Impedance – Headphone Jack	30	Ω
MP3 Quality	128	Kbps
MPEG Layers	I, II and III	
Network Requirement	IEEE 802.11b	
RFID Range	2-6	Inches
Wi-Fi Range	100	ft.
Estimated Battery Life	4.5	Hrs.

B) Cost and Budget

S. No.	Vendor	Part No	Description	Price	Quantity	Cost*	Acquired Cost*
1.	Digikey	497 – 3939 -1- ND	MP3 Decoder	17.14	2	34.28	34.28
2.	Digikey	A323- ND	Decoder Adapter	10.35	2	20.70	20.70
3.	Digikey	HR845CT – ND	SD Card Connector	4.67	1	4.76	4.76
4.	Digikey	ATMEGA – 8535 – 1GPU – ND	Microcontroller	5.70	2	11.4	11.4
5.	Digikey	ATAVRISP2 – ND	Programmer	35.91	1	35.91	35.91
6.	Digikey	CP – 3523SJCT – ND	Audio Jack	0.87	2	1.74	1.74
7.	Digikey	EG1301 – ND	Push Switch	2.15	2	4.30	4.30
8.	Digikey	EG1303 – ND	Push Switch	2.15	1	2.15	2.15
9.	Digikey	EG1308 – ND	Push Switch	2.15	1	2.15	2.15
10.	Circuit City	SDSDPH – 2048 - 901	SD Memory Card	34.99	1	34.99	34.99
11.	Newark	75K7350	D/A Converter	4.06	2	4.06	4.06
12.	Digikey	28141	Rectangle RFID Tag	2.75	3	8.25	2.75
13.	Digikey	28142	RFID Round Tag	2.75	4	11.00	2.75

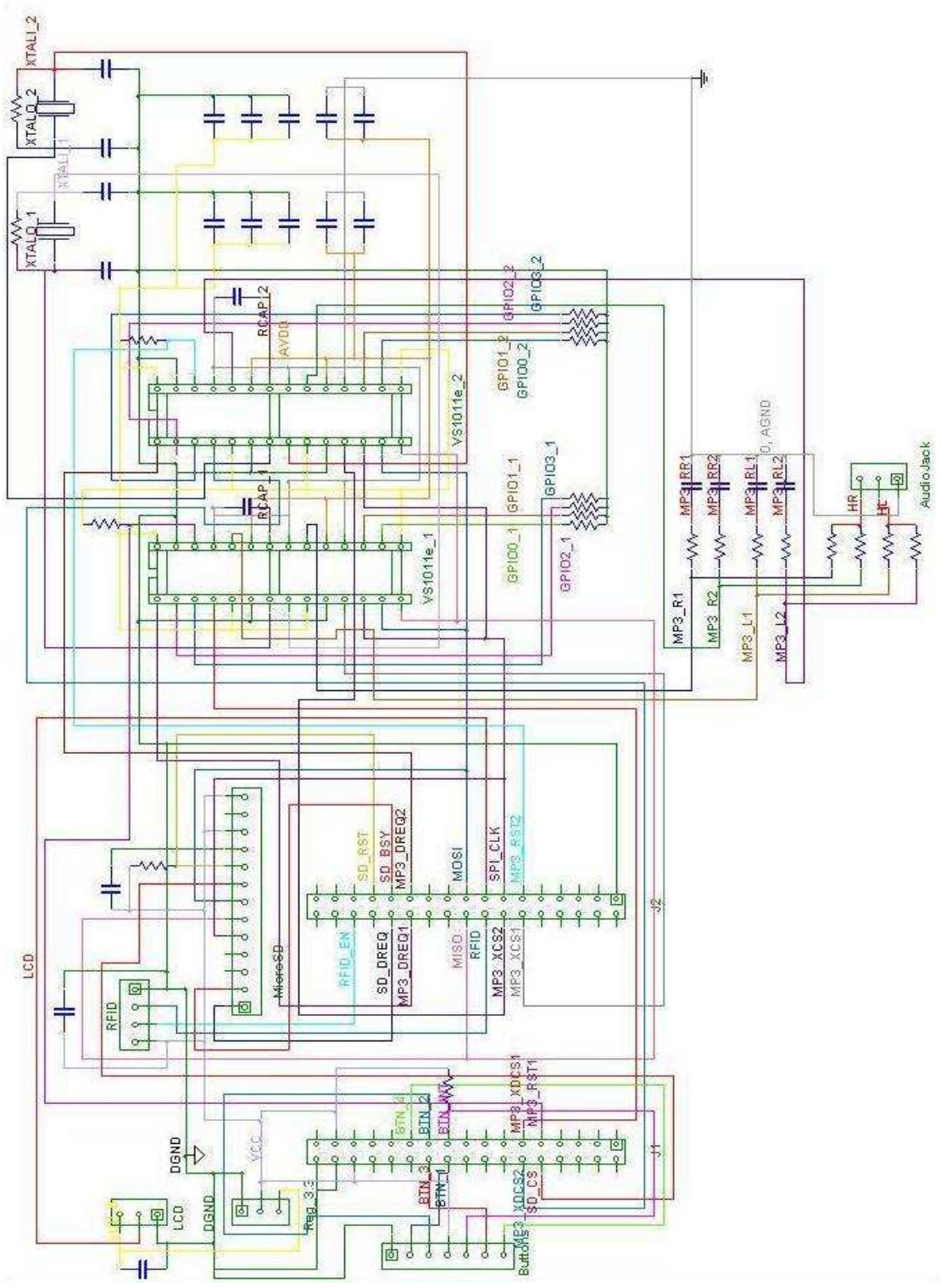
14.	Digikey	28140	RFID Reader	39.95	2	79.90	39.95
15.	Digikey	28148	RFID Disc Reader	2.75	1	2.75	2.75
16.	E-Bay	N 73 OEM Joystick	Joystick	6.98	1	6.98	6.98
17.	Parallax	27979	LCD 20 x 4	46.68	1	46.68	46.68
18.	Sparkfun	BOB - 08215	DosOnChip Breakout	48.25	1	48.25	48.25
19.	Digikey	OP290G	IC OP Amp	5.98	1	5.98	5.98
20.	Digikey	NJM#210	IC OP Amp	0.60	2	1.20	1.20
21.	Digikey	S7120	Connection Header	1.93	4	7.72	7.72
22.	Digikey	497-3939	IC Decoder	17.14	2	34.28	34.28
23.	Digikey	S5750-17	Connection Header	3.48	2	6.96	6.96
24.	Digikey	MX7224K	IC DAC 8 - Bit	7.34	2	14.68	14.68
25.	GHI Electronics	uALFAT	SD Card Reader Module	60.65	1	60.65	0.00
26.	Sparkfun	BOB – 08215	SD Card Reader Module	65.40	1	65.40	0.00
27.	Sparkfun	VS1011e	MP3 Decoder	24.86	2	49.52	0.00
28.	PACTEC	ODNF56-2.5	Enclosure	15.05	1	15.05	0.00
29.	PACTEC	ODNF45-2.5	Enclosure	12.46	1	15.05	0.00
30.	Rabbit	101-0523	Rabbit Development Kit RCM 3000	299	1	299.00	0.00
31.	Rabbit	RCM 3000 Footprint	Wi-Fi Add-on Kit	199	1	199.00	0.00
Total						1134.74	**377.37**

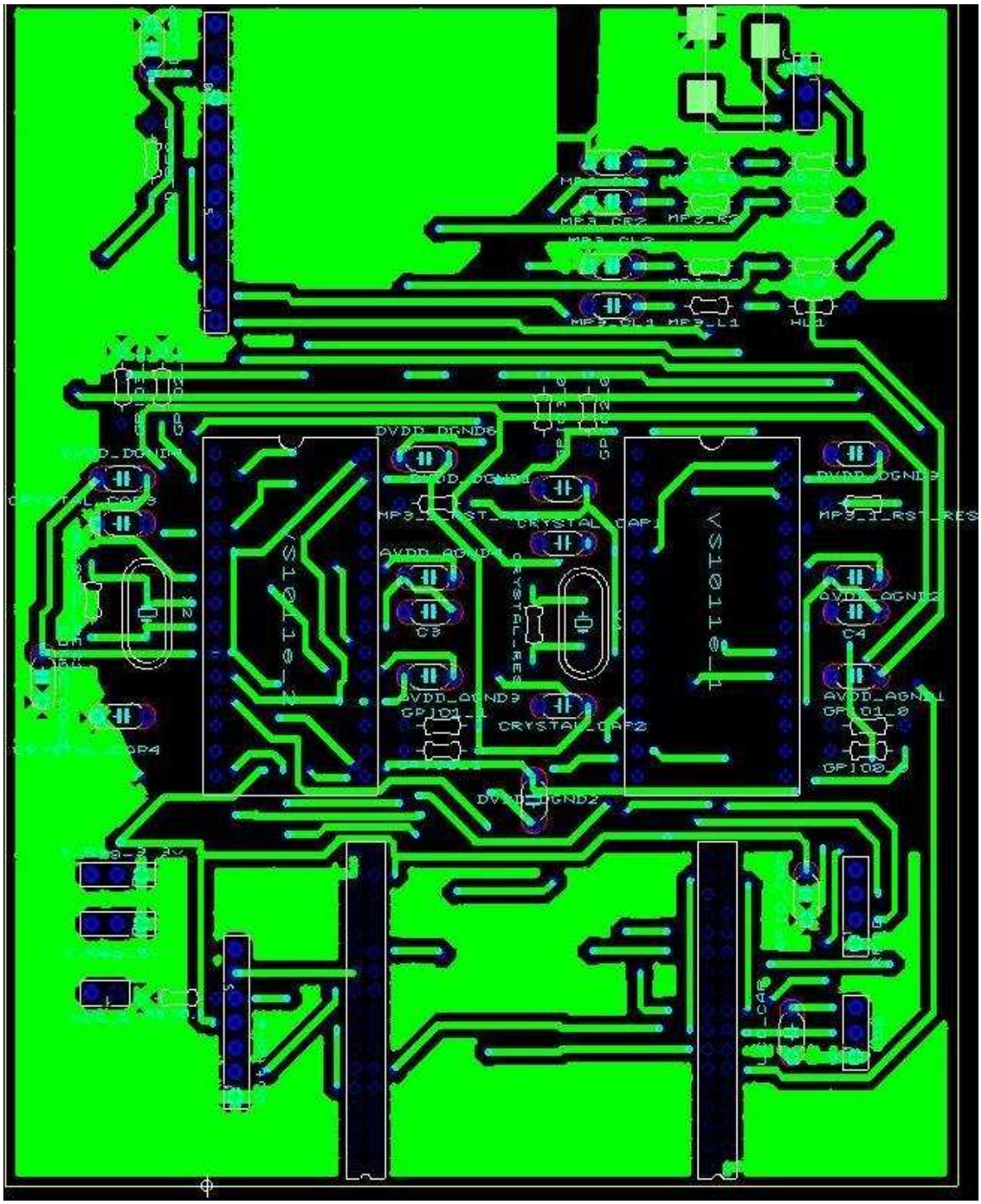
C) What's Next

Currently, we have been able to play just one file at a time with fully functional all the other requirements. After, getting into the details of our inability to do so, we figured out the following issues, which need to be addressed.

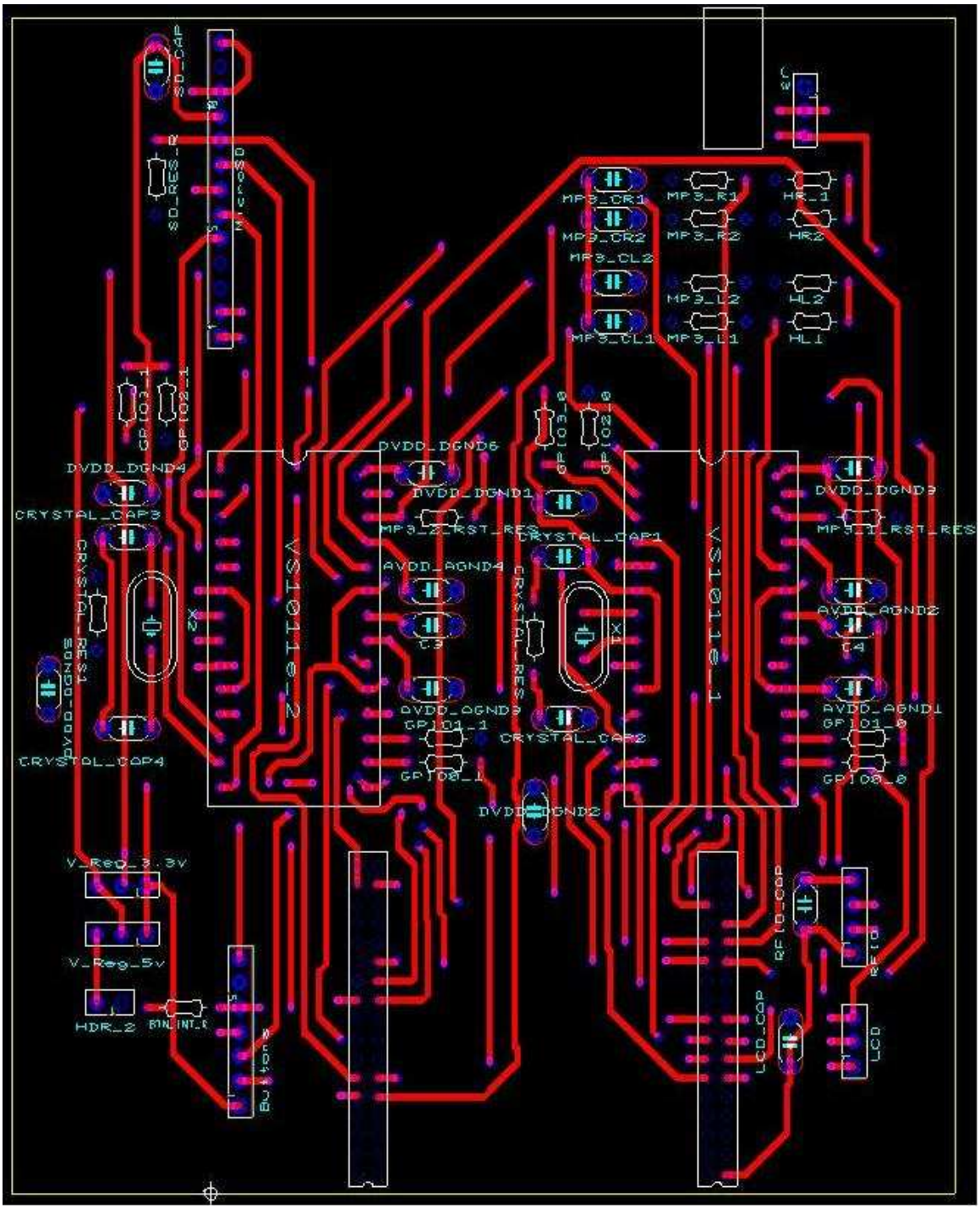
1. The data rate from the SD card is good enough for streaming one file at a time as we are doing right now. However, to play two files we need to switch between files. It was found out that every command takes about 100-150 ms of delay before the SD card responds with valid data. With this huge time lag it is just impossible to read a file and transmit it to the MP3 decoder.
2. The decoder returning us the control characters is also an over head for an application as demanding as this on an embedded hardware. The other reader module that we tried worked for a while and then it stopped working. However, it didn't have any control characters.
3. Other than just adding the ability to play two tracks we would also like to add a colored LCD, a joystick and possibly reduce the size of the device.

D) Schematics & PCB Layout





Copper Top



Copper Bottom

E) Datasheets

F) Software Code

G) Bibliography

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2. www.digikey.com
3. http://www.rfsolutions.co.uk/acatalog/Bluetooth_Remote_Controller_dup.html
4. www.google.com
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6. http://www.myplace.nu/mp3/
7. http://www.pjrc.com
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22. Notes on SD card from F. Foust, Department of Electrical Engineering, University of Michigan
23. Paul Strofferegen,
24. Sana Sidiqque, SD Card Association Member Services
25. US Patent class 704, 369, 482
26. US Patent 6442517
27. US Patent 6631098
28. US Patent 6672991
29. US Patent 6716139